With reference to the drawings, the present invention is directed to a powder coating spray system and a powder overspray recovery system and a color changeover procedure, as well as specific components within such a system, to improve the cleanability and reduce the time to effect color change operations, while at the same time minimizing impact on transfer efficiency while maximizing impact on containment and recovery of the powder overspray. Various aspects of the invention are described herein in an exemplary manner, and as part of an overall spraying system, but such descriptions are not to be construed in a limiting sense. The various aspects of the invention may be used individually or in any various combinations as required for a particular application. Furthermore, although the present invention is described with respect to the use of electrostatic spray technology, the invention is not limited to the use of electrostatic spraying apparatus.

POWDER COATING SPRAY SYSTEM AND POWDER SPRAY BOOTH

Fig. 1 illustrates a powder coating spraying system 1 with several of the main components illustrated in a schematic fashion for ease of illustration. Such components are generally referenced with letters rather than numbers, and are well known and need not be described in detail. Accordingly, the present invention is described in detail as to those elements that relate to the various aspects of the invention.

The system 1 generally includes a spray booth 10. Note in Fig. 1 that the spray booth 10 is represented in a "transparent" manner so that the basic arrangement of components within the booth 10 can be illustrated. In actual practice the booth 10 is made of non-conductive composite materials that are not necessarily transparent, although there is no specific limitation on the choice of materials used for the booth 10. In a preferred but not necessarily required embodiment of the spray booth 10, the booth is constructed from of materials that are very low in conductivity and are composite in nature. These materials render the booth 10 substantially self-supporting and seamless. A suitable manufacturing process and structure for the booth 10 out of such composite materials is fully described in co-pending United States Patent Application serial. No. 09/550,353 filed on April 14, 2000 for POWDER COATING BOOTH CONTAINMENT STRUCTURE, and also described in co-pending PCT Application No. PCT/US 01/40524 filed on April 14, 2001 for POWDER COATING BOOTH CONTAINMENT STRUCTURE, which applications are owned in common by the assignee of the present invention, the entire disclosures of which are fully

incorporated herein by reference. Although these structure and materials for the booth 10 are preferred for electrostatic applications, the present invention is not limited to the use of a booth with such structural and materials characteristics, particularly in systems that will not utilize electrostatic spraying devices.

In the illustrated embodiment, the booth 10 is generally cylindrical in shape, including a vertically extending canopy or wall structure 12, a ceiling, cover or top 14 and a floor 16. In this example, the canopy 12 is realized in the form of two generally hemispherical halves that are joined together by mating flanges (not shown). The halves can be joined by non-conductive fasteners or adhesive so that the basic cylindrical shell is non-conductive. It is preferred although not necessary that the ceiling 14 and the floor 16 also be seamless and made from the same non-conductive composite materials as the canopy. The above-cited patent application discloses a composite booth structure with sufficient strength to permit humans to walk on the floor 16. The canopy 12 is also self-supporting such that no exterior frame is needed to support the booth 10. The canopy 12 and the ceiling 14 may be integrally formed if so desired.

Although the booth 10 is generally cylindrical in shape, it is not a fully enclosed structure. Access doors and other openings are provided to facilitate a spraying operation. For example, a plurality of gun slots 18 are provided on opposite sides of the booth 10 to permit a corresponding plurality of spray guns 20 to extend into and be withdrawn from the spray booth 10. The guns 20 may be of any suitable design, including a gun design as disclosed in co-pending United States patent application serial no. 09/667,663 filed on September 22, 2000 for POWDER SPRAY GUN, the entire disclosure of which is fully incorporated herein by reference.

For clarity and ease of illustration, the spray guns 20 are only illustrated on one side of the booth 10 in Figs. 1 and 1A, it being understood that second set of spray guns and a gun mover may be used on the opposite of the booth 10. The particular system 1 illustrated in Fig. 1 is an automatic system in which the spray guns 20 are mounted on a suitable support frame 22 that is installed on a gun mover 24. The gun mover 24 and the frame 22 are illustrated schematically since any of a number of gun mover and support designs may be used. In this example, the gun mover 24 includes an oscillator 26 that can raise and lower the spray guns 20 along the gun slots 18.

The spray booth 10 however may also be used for manual spraying operations, and therefore may be equipped with an optional vestibule assembly 28 (Fig. 1A only). Preferably the vestibule 28 is made of the same composite materials and structure as the canopy 12.

Continuing with the general description of the system 1, the booth 10 is supported off the shop floor F by a support frame or base 30. The base 30 is supported on the floor F by a pair of parallel rigid bars 32 (only one shown in Fig. 1) which are described in greater detail hereinafter. In accordance with one aspect of the invention, the booth 10 is fully supported on the frame 30 just off the shop floor F such that the entire booth/frame 10/30 assembly can be installed as a retrofit for a preexisting spray booth without the need to modify elevation of the shop floor F or part conveyor height. Thus there is no need to trench or lower the floor F to accommodate any portion of the spray booth 10 or frame 30. In the illustrated embodiment herein, for example, the booth floor 16 is installed a mere 12 inches or so above the shop floor F. This permits simple ductwork to be used to interconnect the various conventional components of the spraying system 1.

The upper portion of the canopy 12 and the ceiling 14 are provided with a conveyor slot 34 that extends diametrically across the entire booth 10. Objects that are to be sprayed are suspended (not shown) from the conveyor C (Fig. 2) in a conventional manner so that the objects can be passed into and through the booth 10 past the spray guns 20.

An extraction duct 40 is installed in the booth 10 in close proximity to the floor 16. This extraction duct 40 has a discharge end is in fluid communication with a dual or twin cyclone separator system 42. In accordance with one aspect of the invention, a substantial negative pressure is produced in the extraction duct 40 via air drawn by operation of the cyclone system 42 and an after-filter system assembly 60 (Fig. 4). A large blower in the after-filter system 60 produces a substantial air flow from the booth 10 interior into the extraction duct 40 in the nature of a vacuuming effect such that powder overspray on the floor 16 is drawn up into the duct 40 and entrained in the air flow therein. This powder laden air is drawn into the cyclone system 42 via appropriate ductwork 44 that connects through an opening in the canopy 12 to the discharge end of the extraction duct 40. The opposite end of the extraction duct 40 terminates at an access door duct (172). The cyclone system 42 exhaust air passes to the secondary after-filter system (60) or collection system (not

shown in Fig. 1) for removal of fines. A dual cyclone arrangement 42a,b is preferably but not necessarily used in order to provide a substantial air flow through the extraction duct 40 to remove powder overspray from the floor 12.

In general, the present invention is described herein with reference to an embodiment in which powder overspray is removed from the booth 10 and fed to a powder collection system. In the described embodiments, the powder collection system includes either a powder reclaim system through operation of a cyclone system and apparatus for conveying powder from the cyclone back to the feed center. Alternatively, in the present application we describe a powder collection system in which the powder is not reclaimed but rather is diverted past the cyclone system directly to an after-filter or other arrangement for the powder to be disposed. The present invention therefore does not depend on the particular powder collection system used outside but rather is directed to extracting powder overspray from within the spray booth, and the term "powder collection" should be construed in its broadest sense to encompass any post-spraying disposition of the powder overspray outside the booth, whether the powder overspray is reclaimed or not.

In Fig. 1 the cyclone system 42 is illustrated as being supported on the shop floor F by a cyclone support frame 43. Alternatively, the cyclone system 42 may be supported directly on the booth support frame 30.

The air flow that is drawn through the extraction duct 40 also provides a containment air flow within the booth 10 interior. Substantial volume of air is drawn into the booth 10 via various openings and access doors provided in the canopy 12.

The extraction duct 40 is supported at each end by the base 30, not the booth floor 16. The canopy 12 and installed ceiling 14 are also supported by the base 30 and not the booth floor 16. In accordance with another aspect of the invention, the booth floor 16 is rotatable about the central longitudinal axis X of the booth 10. The extraction duct 40 in this case is stationary relative to the rotating floor 16 so as to provide a sweeping action between the extraction duct 40 and the floor 16 surface. In this manner, the floor is cleaned of powder overspray as it collects on the floor even during a spraying operation. Of particular note is that the overspray may be extracted during or after a spraying operation.

Completing the general description of the system 1, the cyclone system 42 may be conventional in design and separates the entrained powder from the drawn air. The system 1 also includes a powder feed center 46 that supplies powder to the spray

guns 20 through an appropriate system of a feed hopper, feed hoses and powder pumps, as is well known to those skilled in the art. A control console or system 48 is also provided that controls the operation of the guns 20, the cyclone system 42, the gun movers 26, the conveyor C, floor 16 rotation and position, and the feed center 48. The control system 48 may be conventional in design. Suitable control systems are described in United States Patent Nos. 5,454,256 and 5,718,767; a suitable cyclone system is disclosed in United States Patent No. 5,788,728; and a suitable feed center is disclosed in United States provisional patent application serial no. 60/154,624 which corresponds to copending PCT application number 00/25383 filed on September 15, 2000 for QUICK COLOR CHANGE POWDER COATING SYSTEM, the entire disclosures all of which are fully incorporated herein by reference. Powder that is separated by the cyclone system 42 may be returned to the feed center 46 for reuse (not shown in Fig. 1).

In accordance with another aspect of the invention, the floor 16 not only can rotate, but also can be axially translated along the axis of rotation X. This permits the floor 16 to have at least two axial positions, the first being a lowered position in which the floor 16 is free to rotate during a spray coating operation, and a second position in which the floor 16 is raised and is sealed against the lower edge of the canopy 12 walls during a color change operation. By moving the floor 16 into the sealed or raised position, an operator can use an air wand or other suitable device to blow down powder overspray that may have collected on the canopy 12, the ceiling 14 or the outside of the extraction duct 40, into the extraction duct 40. For example, the extraction duct 40 is preferably at least partly made of metal to act as an ion collector for electrostatic spraying systems. Consequently, powder will adhere and collect on the outer surface of the extraction duct 40, but this small amount of powder can quickly and easily be blown off and will be quickly swept up into the duct 40. The blower assembly 60 preferably remains on at all times during spraying and cleaning/color change operations.

In its raised position, the floor 16 is fully supported (as will be described herein) so that one or more operators may walk across the floor as required for air cleaning the booth 10, usually as part of a color change operation. The floor 16 is then lowered and rotated while operating the cyclone system 42, thereby removing the last remaining quantities of overspray. Color change therefore is a very fast and simple procedure in terms of cleaning out the spray booth 10. The preferred use of

the composite materials for the booth 10 substantially eliminates powder collecting on the canopy 12 and ceiling 14, and permits the extraction duct 40 to easily and efficiently remove powder from the floor 16. The floor 16 is non-conductive except at the drive hub assembly (not shown in Fig. 1), but the drive hub assembly is located within the extraction duct 40 such that powder cannot collect at the hub due to the high air flow through the duct 40.

The outside surfaces of the housings or bodies of the guns 20 may be cleaned by air jets 21 (Fig. 4) that are positioned at the gun slots 18. As illustrated in the enlarged portion of Fig. 4, the air jets 21 (one for each gun body) are installed on a common air tube 21a that extends vertically along the length of its associated gun slot 18. In this embodiment there is an air tube/jet arrangement for each gun slot 18. The air jets 21 blow high pressure air across each gun body as the guns 20 are withdrawn from the booth 10 by the gun movers 24, thereby cleaning powder from the guns 20 and blowing powder off the gun bodies into the booth 10 where it is extracted via the extraction duct 40.

A significant aspect of the system 10 is that it can be realized as part of a retrofit on an existing system without the need for major changes to the shop area. For example, in the illustrated embodiment, the booth floor 16 is a mere 12 inches above the shop floor F. This permits the booth 10 to be interconnected if required with preexisting cyclone and feed systems, as well as fitting under existing conveyor systems.

With reference to Fig. 2, the spray booth 10 is illustrated in a simplified manner from a top or plan view with the base 30 and the ceiling 14 omitted. The canopy 12 includes access doors 50 that permit larger objects to be conveyed into the spray booth 10. As illustrated in Fig. 1, the doors 50 may be similar to a "dutch" door arrangement in which there are upper doors 50a and lower doors 50b. The lower doors 50b are typically opened simply to permit an operator easy access to the booth 10 interior. These openings provide the major source of air that enters the booth 10 during a spraying operation when the cyclone system 42 is operating. This primary air flow pattern serves as containment air to keep the powder overspray within the booth 10. Although air flow will also be produced in other areas of the booth 10, for example at the conveyor slot 34, these secondary openings and gaps contribute much less to the overall containment air pattern than the air entering through the various door openings and any vestibule when vestibules are used. The diametric centerline

Y of the primary air flow pattern, such as for example through the access doors 50, forms an angle α with the centerline Z of the extraction duct 40. Preferably the angle α is about 45 degrees. Thus the air flow (as indicated by directional arrows AA) into the booth 10 is not parallel with the extraction air flow into the duct 40. This causes air flowing into the booth 10 to have to turn and head downward (see also Fig. 4) in order to reach the low pressure zone near the extraction duct 40 along the floor 16, as represented by the directional arrow AA. This air flow pattern thus produces a descending outer air circulation around the booth 10 that results in a relatively low air flow in the central region of the spray booth 10, which central region is where the spray guns 20 are disposed to spray an object. This relatively calm central region means that the powder spray patterns are not adversely affected by the rather high volume of containment air flowing into the booth 10. Thus, excellent powder containment is effected without a significant effect on the transfer efficiency of the guns 20.

Figs. 3 and 4 illustrate in plan a typical floor layout for the system 1 (the spray booth 10 is illustrated in vertical cross-section). Note that in Fig. 4 we illustrate the use of two gun movers 22. In this arrangement, the cyclone system 42 is connected to the outlet of the extraction duct 40 by a transition elbow duct 52. The powder laden air flows from the extraction duct 40, into the elbow 52 and up the vertical connecting ductwork 44 to the tangential inlet 54 of the cyclone 42. The cyclone system 42 includes a bypass plenum 56 that has a reclaim/non-reclaim bypass valve therein, which will be described further hereinafter. When the cyclone is in a "reclaim" mode of operation, the cyclone exhaust air, which typically still includes powder fines that were not removed by the cyclonic filtering action, passes through additional exhaust ductwork to a conventional after-filter assembly 60 (Fig. 4). Powder that is separated by the cyclone 42 falls into a cyclone hopper 62 (Fig. 3) from where it can be manually removed and returned to the feed center 46 main hopper (not shown) or can be automatically transferred to the feed center 46 by positive air pressure and appropriate ductwork, valves and filters. In prior art systems, a pinch valve assembly (not shown) has sometimes been installed below the cyclone hopper 62 to control the transfer of the reclaimed powder from the cyclone 42 to the feed center 46. In the non-reclaim mode of operation, the cyclone system 42 is in effect taken off line by operation of the bypass valve, so that the powder laden air from the extraction duct 40 passes through the ductwork 44 and straight through the plenum 56 to the exhaust

duct 58 and from there into the after-filter assembly 60. Note that the main blower (not shown) for producing the needed air flow within the booth 10, the extraction duct 40, the cyclone system 42 and the interconnecting duct work is physically located in the after-filter assembly 60. The main blower can be conveniently located elsewhere in the overall system as required.

Fig. 4 shows schematically some additional detail of a suitable gun mover 24. Note that the view angle of Fig. 4 is rotated from the view angle of Fig. 3 to show additional details, and that in Fig. 4 the cyclone system 42 has been omitted for clarity. The guns 20 are mounted on a frame or gun mount 22 which typically includes a number of tube lengths arranged horizontally and vertically to allow the guns 20 to be positioned as required. The oscillator 26 is supported on a moveable platform 64 that can translate back and forth on a base 66. The platform 64 is moved pneumatically or but other suitable means by the control system 48 so as to move the guns 20 horizontally into and out of the booth 10. The oscillator 26 moves vertically to allow the guns to be raised and lowered during a spraying operation. Preferably but not necessarily the gun mover bases 66 are supported on wheel assemblies 106 (Fig. 6) that allow the gun movers 24 to be rolled across the shop floor (see Fig. 6). This allows the gun movers 24 to be part of an overall modular spraying system in that various main components can be added on and separately assembled to the booth 10 and frame 30 assembly as required.

With reference to Fig. 5, the support frame 30 is realized in the form of a octagonal framework although the actual geometry and configuration may be selected as required. The inner perimeter configuration of the frame 30 however is circular to accommodate the booth floor 16. The frame 30 includes a series of interconnected trusses 68 and frame bars or spars 70. A removable skirt or cover 72 is provided for aesthetics and to prevent accidental contact with the rotating floor 16. The frame 30 also supports various equipment such as a floor drive motor 74 and a series of four floor lifters 76. The bottom of the frame 30 rests on two parallel floor base support bars 32. As shown in greater detail in Fig. 6, the support bars 32 have wheels or casters 78 installed on each end. This permits the entire booth 10 and frame assembly 30 to be easily moved into position on the shop floor F.

The dashed lines W represent where the booth vertical canopy 12 walls align with the frame. The circle FL indicates the outer perimeter of the booth floor 16. Thus it is apparent that the floor 16 diameter is greater than the diameter of the

canopy. In a typical booth, the canopy may be about 10 feet for example in diameter and the floor 16 may be about 11 feet in diameter. There is no practical restriction on the booth size however. The floor 16 extension past the canopy 12 wall acts as a fall-out pan so that powder that escapes through the gap between the floor 16 and the canopy 12 will alight on the extension. This amount of powder is typically going to be very small and consist mainly of fines and thus will tend to be drawn in by operation of the extraction duct 40, as well as a seal blow-off jet that will be described hereinafter.

A parallel pair of floor hub supports 82 extend across the inner perimeter of the frame 30. These hub supports are rigidly mounted to the frame 30. As will be further explained hereinafter, the floor 16 is mounted on the supports 82 via a hub assembly 84. Thus, the floor 16 is fully supported on the frame 30 as a unit separate from the canopy 12 to permit rotation and vertical movement of the floor 16 relative to the canopy 12.

The frame 30 supports a number of floor lifter units 76, which in this embodiment there are four lifters 76 evenly spaced around the frame 30. The basic function of the lifters 76 is to raise and lower the floor 16 vertically relative to the bottom edge of the canopy 12 walls. When the floor is raised, it is sealed against the bottom edge of the canopy 12. When in the lowered position, the floor 16 is free to rotate about the longitudinal axis X of the canopy, which is also the translation axis for the vertical movement of the floor 16.

As noted hereinbefore, the frame 30 also supports the ends of the extraction duct 40, and more specifically in this embodiment the transition duct to the cyclone system and the access door assembly at the opposite end. This permits the extraction duct to be supported in a position that is just above the top surface of the floor 16 when the floor 16 is rotating. The extraction duct 40 is not shown in Fig. 5.

With reference next to Figs. 6 and 7, the floor 16 includes a thicker middle section 16a and then at its periphery thins down to a rigid flange portion 16b. Four floor lifter units 76 are evenly spaced about the periphery of the floor 16 (see Fig. 5), and Figs. 6 and 7 illustrate in detail one of the lifters 76, with the other three lifters being substantially the same. Although the lifter 76 design illustrated herein is a preferred design, those skilled in the art will readily appreciate that there are many available alternative ways to raise and lower the floor 16, especially since the displacement is rather short, on the order of about two inches or less. It is only

necessary to lower the floor 16 from the canopy 12 to provide enough clearance so that the floor 16 can rotate freely. The smaller the gap between the floor 16 and the bottom of the canopy 12 wall 12a, the easier it is to contain powder from alighting beyond the canopy 12 wall periphery.

Each lifter 76 comprises three basic elements, namely a pneumatic actuator 90, a rocker arm 92 and a roller 94. In this embodiment, the pneumatic actuator 90 is realized in the form of a conventional air cushion shock commonly found in pneumatic suspension applications. The actuator 90 includes an inflatable bladder 96 that is supported by a pinned flange 98 on one of the trusses 70 of the frame 30. Pressurized air is supplied to the bladder 96 via an appropriate fitting and air hose assembly 97. The lower end of the bladder is attached or otherwise displaces a flange 100 that is pinned to a first end 92a of the rocker arm 92. The roller 94 is pinned to the opposite end 92b of the rocker arm and engages the underside of the floor 16 at the region of the floor flange portion 16b.

The rocker arm 92 is bent approximately at its middle and pinned at 102 to the frame 30 so as to be able to pivot about the axis of the pin 102. The control system 48 may be used to control the air pressure applied to the bladder 97, or this may be a manual control operation. In either case, all four lifters 76 are preferably but not necessarily actuated at about the same time in order to maintain the floor 16 generally level. When the bladder 96 is inflated by the application of pressurized air, the bladder 96 expands thus pushing down the flange 100 which pushes down the first end 92a of the rocker arm 92. This causes the rocker arm to pivot in a counterclockwise direction (as viewed from the illustration in Fig. 6). The counterclockwise pivoting action raises the roller 94 thus raising the floor 16. The floor 16 will be raised until it engages with the lower edge of the canopy wall 12a. This is the raised and sealed position of the floor 16 as shown in Fig. 6, and the floor is non-rotating when in the raised position. An elastomeric seal 104 or other suitable seal is disposed on the floor 16 and engages the lower end of the canopy 12a when the floor 16 is raised into sealing engagement with the canopy 12.

At least one air jet nozzle 80 is positioned on the frame 30 at the perimeter of the floor 16 to direct pressurized air at the seal 104 when the floor 16 is in its lowered position. This air jet 80 cleans the seal 104 of any overspray powder after cleaning activities inside the booth 10 are completed in preparation for a color changeover. The air jet 80 is not otherwise turned on as it is typically not needed. The nozzle 80 is

preferably positioned near one end of the extraction duct 40 so as to blow powder from the seal 104 directly into the duct 40. The small air movement induced by the nozzle 80 will be sufficient to draw powder that has alighted on the floor 16 extension 16c outside the canopy 12 wall to be swept into the duct 40.

The circumferential elastomeric floor seal 104 is affixed to the floor 16 or carried on the bottom of the canopy 12 and forms an air tight seal between the floor 16 and the canopy 12 when the floor is in the raised position. Any suitable seal or gasket material may be used for the floor seal 104. This permits an operator to enter the booth 12 when the floor is in its raised position and use an air wand or other mechanism to blow powder off the canopy walls, ceiling and the extraction duct 40 without blowing powder out the booth between the floor 16 and the canopy 12 or having powder get trapped between the floor 16 and the canopy 12. This cleaning operation will typically be performed as part of a color change operation.

When the air pressure in the bladder 96 is relieved, the bladder 96 contracts and pulls up the first end 92a of the rocker arm, thus causing the rocker arm 92 to pivot clockwise (as viewed in Fig. 6). This rotation lowers the roller 94 and the floor 16 lowers under the force of gravity with the roller 94. The roller 94 lowers until it contacts the frame 30. As will be described herein shortly, the floor 16 is mounted on the hub assembly 84 that not only permits the floor to be rotated but also allow for this axial displacement of the floor 16 relative to the canopy 12.

Fig. 6 also illustrates that the gun mover base 66 may be supported on wheel assemblies 106 so that the gun movers 22 may be easily connected and disconnected from the booth frame 30. A pinned connection 108 may be used to releasably connect the gun mover base 66 to the frame 30.

Fig. 6 illustrates another aspect of the invention. Since the floor 16 is rotated during spraying and color change/cleaning operations, the canopy 12 and the ceiling 14 need to be supported separate from the floor 16. This is accomplished in the illustrated embodiment by the use of hanging knees 110 that are positioned around the frame 30. Each knee 110 includes a lower horizontal flange 112 that is bolted or otherwise secured to the frame 30. The knee 110 extends up then inward toward the booth 12. The knee further includes a vertically extending flange 114 that may be slightly curved to match the curvature of the canopy 12 wall. It is preferred although not required that the knees 110 are made of non-conductive composite materials, such as in accordance with the processes described in the above-referenced patent

application. However, the knees 110 may be made from any non-conductive material provided that the knees 110 have enough rigidity and strength to support the canopy 12 and ceiling 14.

Each knee 110 is bonded to its respective portion of the canopy 12 outer wall surface. Any suitable bonding agent may be used and will be determined based on the materials of the knee 110 and the canopy 12. By this arrangement, the canopy 12 and ceiling 14 are fully supported just above the floor 16 (which extends under the canopy 12 wall as in Fig. 5) and there are no conductive bolts or plates or other elements that would attract the electrostatically charged powder. The use of the composite materials for the canopy 12 makes the canopy a fully self-supported structure that is cantilevered over the floor 16.

In an alternative embodiment illustrated in Fig. 17, the canopy 12 wall is attached to a plurality of hanging knees 190 by screws 192. In Fig. 17 the floor 16 is shown for reference purposes. Note in this embodiment that the lower end 12a of the canopy 12 wall is substantially reduced in thickness to provide a mounting flange that is attached to a flange on the hanging knee 190. Each knee 190 is also bolted to a corresponding support truss 70 or other firm structure on the booth support frame 30. Fig. 17 further illustrates the provision of the non-conductive plastic shroud 72 that overlays the frame 30 to keep dust out of the frame interior and for aesthetic value.

With reference to Figs. 8 and 9, the floor 16 is a multi-layer construction of composite materials. The floor 16 includes an inner hub hole 120 formed by an integral annular hub flange 122. As best shown in Fig. 9, the floor 16 is built up in a step-wise fashion so as to have its greatest thickness in the middle region of the floor 16. The layers are then step-wise eliminated such that the outer perimeter of the floor is formed by the flange 16b. With reference to Figs. 8 and 9, the inner hub flange 122 includes four bolt holes 124 that receive mounting bolts to attach the floor 16 to the hub assembly 84. Fig. 9 further shows schematically the laid-up construction of the composite floor 16 when the floor is made in accordance with the processes described in the above-incorporated patent application. The floor 16 upper or active surface 126 is a layer of gelcoat while the underside surface 128 is a layer of epoxy barrier. In between these two layers are layers of PVC coring 130 and bi-directional fabric 132. The resulting floor 16 has very high strength and rigidity and very low conductivity, therefore, powder overspray will not easily adhere to the floor upper surface 126.

With reference to Figs. 10 and 11, the hub assembly 84 is supported by the parallel hollow bar hub supports 82 which extend across the frame 30 (Fig. 5) and are mounted to the frame 30 by bolts or other suitable means (not shown). Mounted on each support bar 82 is a gear box support bracket 140. Each bracket 140 may be attached to its respective support bar 82 by bolts 142 for example. A gear reducer box 144 is mounted on the brackets 140 by bolts 146. The gear reducer 144 drives a spline shaft 148 in response to rotation of a drive shaft 150 that is coupled to the gear box 144 by a universal joint 152. The drive shaft 150 is turned by a ¼ horsepower motor 74 that is mounted on the frame 30 as described hereinbefore.

The spline shaft 148 meshes with a track ball spline 154 that has an inner spline for the spline shaft 148 and an outer spline that meshes with a coupling 156. The coupling 156 is mounted on an aluminum hub plate 158 by a cap 160 that is attached to the coupling 156 by bolts 162, and a collar 164 that is attached to the coupling 156 by bolts 166. The floor 16 is mounted on the hub plate by bolts 168 that pass through the floor hub flange 122 bolt holes 124 (Fig. 8).

By this arrangement, the motor 74 turns the drive shaft 150 through a gear reducer 170, with the drive shaft turning the spline shaft 148 through the gear reducer 144 that is mounted on the frame 30 via the support bars 82. The spline shaft 148 rotation thus rotates the floor 16 via the coupling 156. By use of the spline arrangement between the drive shaft 150 and the hub plate 158, the floor 16 can be axially translated along the axis X a limited distance as previously described herein under operation of the floor lifters 76. The control system 48 may be programmed to set or adjust the motor 74 speed and hence the floor 16 rotation speed.

With reference to Figs. 12, 12A, and 13-14, the extraction duct 40 in this embodiment is a metal duct that is mounted on one end to the cyclone elbow duct 52 and at the other end to an access door duct 172. The cyclone elbow duct 52 and the access door duct 172 are both mounted on the frame 30 and support the extraction duct 40 just off the floor 16. For reference, the canopy 12 wall location is shown with dashed lines W in Figs. 12 and 13, and the floor FL is also represented.

The extraction duct 40 includes a lower skirt 174 that tapers downwardly towards the floor 16 along the longitudinal axis of the duct 40. This taper is defined by an angle β. The extraction duct 40 is supported about two inches above the floor 16, and the small optional taper β is used to maintain a constant air flow pattern through the duct 40. Without the taper, the higher negative air pressure closest to the

cyclone inlet 52 would cause an uneven flow pattern within the booth. When the floor is in the raised position, there is only a very small or zero gap between the duct 40 and the floor 16 at the cyclone duct 52 end, and about two inches at the opposite end. Thus at its maximum when the floor 16 is lowered, the opposite end has about a four inch or less gap between the bottom of the duct 40 and the floor 16.

As best illustrated in Fig. 14, the duct 40 further includes two doors 176a and 176b that are attached to the skirt 174 by suitable hinges 178. The hinges 178 allow the doors 176 a,b to open as illustrated in phantom in Fig. 14 to prevent excessive pressure build-up in the duct 40. Pressure can build up inside the duct 40 when the floor 16 is in the raised position during booth cleaning and as part of a color change operation. But under normal operating conditions, the doors 176a,b are closed and held closed by the negative air pressure within the duct 40. As the floor rotates under the duct 40, powder on the floor 16 is drawn up into the air stream inside the duct 40 and carried out to the cyclone system 42.

With reference to Figs. 15A, 15B and 16, in an alternative embodiment the extraction duct 180 may be partially made of composite materials similar to the materials used for the booth 12. The duct 180 includes two longitudinal metal rails 182 that extend in parallel across the floor 16 and that are joined at the top by a cover 184. The rounded cover reduces powder buildup on the duct 180 and therefore is preferably but not necessarily made of composite very low conductivity materials. In contrast to the embodiment of the all metal duct 40, the cover 184 is a two piece cover 184a,b with each half hinged at the outer longitudinal ends thereof. The covers thus lift vertically from the lengthwise center point of the duct 180 when open as illustrated in phantom in Fig. 15B and extend up along the canopy wall. Fig. 16A illustrates another alternative embodiment in which the composite cover 184' comprises two halves 184a' and 184b' that are hinged lengthwise in a manner similar to the embodiment of Fig. 14. As in the embodiment of Figs. 15A and 16, the composite duct cover 184' may, for example, be made using the processes for making the composite booth 12.

The duct 180 is mounted above the floor 16 and may be installed in a manner similar to the all metal duct 40 embodiment. In accordance with another aspect of the invention, in some applications it may be required to apply additional force to the powder residue that adheres to the floor 16 if the suction from the duct is insufficient to thoroughly dislodge the powder. In the embodiment of Figs. 15 and 16, the

composite duct 180 may be formed with internal air passageways 186 within the rails 182 through which pressurized air is supplied (not shown). Each rail 182 is arcuate in shape so as to include an end portion 182a that lies on a tangent T that forms an included angle θ with the floor 12. The angle θ is preferably less than ninety degrees.

A series of air jets or orifices 188 are formed in the bottom of each rail 182 and are in fluid communication via passageways 188a with the air passageways 186 such that pressurized air is directed out of each orifice 188 against the floor but at an angle that causes powder on the floor 12 to be blown into the extraction duct 180 interior. The orifices 188 are spaced along the lower edge of each rail 182 on the approach side of the extraction duct 180, thus for each rail 182 the orifices 188 are provided only on one half of each respective rail but a complete line of orifices extend across the entire booth floor 16. This positive pressure air from the jet slots 188 augments the powder removal suction caused by the negative air pressure flow within the duct 180. The pressurized air from the orifices 180 will tend to assist in dislodging powder overspray particles that may have adhered to the floor 12 and cannot be drawn up by the negative air pressure flow from the duct 180. The alternative duct 180 embodiment need not be made of the same materials as the booth 12, however, use of such materials will result in minimal collection of powder overspray on the duct 180.

CYCLONE BYPASS VALVE

With reference again to Fig. 3, it is sometimes desired to be able to select whether the powder spraying system 1 operates in a powder reclaim or non-reclaim mode. For example, the system 1 may be operated in a non-reclaim mode when the powder overspray cannot be returned to the feed center for re-use. Since the reclaim powder mode of operation involves the use of the cyclone system 42, it is necessary to in effect take the cyclone 42 "off-line" for the non-reclaim mode.

Fig. 18 shows a bottom view of the bypass plenum 56. Each of the twin cyclones 42a,b have circular exhaust openings that align with openings 200 and 202 in the bypass plenum 56. In the reclaim mode, exhaust air from the cyclones 42a,b enters the bypass plenum 56 through the openings 200 and 202 and passes through the plenum outlet or exhaust opening 204 to the after-filter ductwork 58. In the non-reclaim mode, the openings 200, 202 are closed off by a bypass valve assembly 206.

With reference to Fig. 3, the vertical ductwork 44 that connects the extraction duct 40 to the cyclone system 42 is connected to a plenum manifold 207 that includes

a first duct 208 that is connected to the cyclone inlet 54 (keeping in mind there are two such inlets when twin cyclones are used) and also includes a cyclone bypass duct 210. The bypass duct 210 extends over the top of the cyclone system 42 and is connected to the bypass plenum 56.

With reference to Figs. 19A and 19B, the bypass valve 206 includes three basic components, namely a valve door 212, seals in the form of a pair of cyclone outlet seals 214 and a bypass duct seal 216, and a valve actuator mechanism 218. The valve door 212 is disposed within the bypass plenum 56 and is therefore shown in phantom in Figs. 19A and B, whereas the valve actuator mechanism 218 is disposed outside the bypass plenum 56. In Fig. 19A the valve door 212 is shown in the cyclone open position and in Fig. 19B the valve door 212 is shown in the cyclone closed position which correspond in this embodiment to the reclaim and non-reclaim modes respectively.

The seals 214 and 216 are, for example, conventional D-seals. The cyclone seals 214 are installed on the plenum 56 around each of the cyclone openings 200, 202. Alternatively, the cyclone seals 214 may be installed on the valve door 212. The bypass plenum seal 216 may also be a D-seal and is installed in the plenum 56 around the opening between the bypass duct 210 and the bypass plenum 56. Again, alternatively, the duct seal 216 may be installed on the valve door 212 rather than the plenum 56 wall.

When the valve door 212 is in the upright or cyclone open position, the valve door 212 seals and isolates the bypass duct 210 from the bypass plenum 56. The cyclone exhaust outlets are also open to the bypass plenum 56 via the openings 200, 202. As a result, the powder overspray laden air from the extraction duct 40 passes into the cyclone inlets 54 whereby much of the powder is separated from the air stream and drops to the lower collection regions of the cyclones. The cyclone exhaust air, which may still contain powder fines, flows through the after-filter ductwork 58 to the after-filter assembly 60 (Fig. 4).

When the valve door 212 is in the down or cyclone closed position (Fig. 19B), the door 212 seals off and isolates the cyclone exhausts from the bypass plenum 56. The bypass duct 210 however is now open to the bypass plenum 56. When the cyclone exhausts are sealed off, the cyclone system 42 is non-operational and represents a high pressure impedance to the flow of air into the cyclone inlets 54. As a result, the powder laden air from the extraction duct 40 bypasses the cyclone inlets

54 and passes through the bypass duct 210, then straight through the bypass plenum 56 into the after-filter ductwork 58 and finally to the after-filter assembly or other waste receptacle.

The valve actuator mechanism 218 in this embodiment is realized in the form of a pneumatic piston type actuator 220 and a bell crank assembly 222. The bell crank assembly 222 is a lever 224 that is connected at its free end 226 to an actuator rod 228, and at its opposite or pivot end 230 is connected to the valve door 212 through the plenum 56 wall. The actuator 220 is pivotally connected to a mounting bracket 232 so that the actuator 220 is free to rotate slightly to avoid binding as it pushes and pulls on the bell crank lever 224. The actuator 220 may be controlled by the control system 48, or alternatively may be controlled by manual operation of a pressure valve. Still further, the valve door 212 could be manually moved, but an actuator is preferred to assure a good seal when the door 212 is in each position.

Figs. 20 and 21 illustrate one embodiment of the valve door 212. The door 212 includes two faces 212a and 212b each of which will overlay respective openings 200, 202 to seal off the cyclone 42 when the door 212 is in the non-reclaim position, and cover the inlet from the bypass duct 210 when the door 212 is in the non-reclaim position. The door 212 is formed of a piece of sheet metal 232 that is bent around an actuator bar 234. One end of the actuator bar 234 is connected to the pivot end 230 of the bell crank lever 224 (Fig. 19). The door 212 is enclosed at its end and top with additional sheet metal and then injected with foam for strength and rigidity. In an alternative form of the door 212, a pair of doors may be used that individually pivot to close each cyclone exhaust opening. In this alternative, a separate third door may be needed to close off the bypass duct 210 when the system 1 is used in the reclaim mode.

It should be noted that the cyclone bypass valve concept may be used in any powder spraying system that utilizes a cyclone separator system. The bypass valve arrangement is therefore not limited to use in a system that uses other aspects of the system described herein such as, for example, the embodiments of the spray booth 10.

POWDER OVERSPRAY RECOVERY SYSTEM

With reference next to Fig. 22, the general concepts of a powder overspray recovery system 300 is illustrated in functional schematic form. A significant aspect of the invention is that most of the powder overspray P is extracted from the spray booth 10 and transferred back to the feed center 46 with as little residence or dwell

time as possible within the various system 300 components, during a spraying operation. Thus when the need arises to changeover the color of the powder, there is little powder remaining in the system 300 that needs to be removed. In addition, the invention contemplates various components and subsystems within the recovery system 300 that facilitate fast cleaning and color change, as will be further explained herein.

Conceptually then, the powder recovery system 300 actually starts in the spray booth 10 wherein most of the powder overspray P falls onto the floor 16. As previously explained herein, the booth walls or canopy 12, the top 14 and the floor 16 are preferably although not necessarily made of non-conductive composite materials which exhibit very low adherence of the powder. A high capacity blower 302 which in this embodiment is installed in the after-filter system 304, produces a large suction and attendant air flow through the twin cyclone system 42 and hence the extraction duct 40 inside the spray booth 10. The round floor 16 is rotating underneath the extraction duct 40 and thus the powder overspray is drawn up into the extraction duct 40 and transported to the inlets 54 of the cyclones 42. Although twin cyclones are used in the embodiment as a first collection device, the invention may be realized with one or more cyclone structures. Due to the non-conductive materials of the booth 10 and the efficient arrangement of the rotating floor 16 and the extraction duct 40, most of the powder overspray during a spraying operation is extracted from the booth 10.

As part of the spraying system, Fig. 22 illustrates that one or more spray guns 20 are each connected by a powder feed hose 306 to a respective powder pump 308 in the feed center 46. Each powder pump 308 draws powder from a feed hopper 310 via a suction tube 312 that extends down into the hopper 310. The feed center 46 typically, although not necessarily, is a separate partially enclosed booth that houses the feed hopper 310, the various pumps 308, and a purging system (not shown in Fig. 22 but described hereinafter). Although various improvements in the pumps and purging arrangement are described herein as additional aspects of the invention, it will be readily appreciated by those skilled in the art that the basic powder recovery system of the present invention may be realized and practiced with conventional powder feed arrangements. The basic combination of a feed hopper or powder source, suction tubes, powder pump, powder feed hose and spray gun is referred to herein as a powder application system, and thus includes elements that physically are

installed in the powder spray booth 10 and the feed center 46, with the feed hoses 306 being connected therebetween.

Continuing with the general description of the powder recovery system 300, the cyclone system 42 separates the powder overspray P from the extraction air stream, and most of the powder is discharged from the bottom of the cyclones 42. The air is exhausted through the cyclone outlets 42a,b and after-filter ductwork 58. This exhaust air is sent to the after-filter assembly 304 because the cyclones 42 cannot remove 100% of the powder, especially the very small low mass powder particles called fines. The after-filter system 304 is used to remove these fines before the air is exhausted to atmosphere.

A conventional cyclone system 42 typically would include a conical hopper and pinch valve arrangement at the bottom of the cyclone that collects powder and then is periodically emptied under positive pressure back to the feed center or to waste. In accordance with a significant aspect of the invention, negative pressure is used to convey powder from the cyclone system to the application system or feed center 46. In one embodiment, the conventional hoppers and valves are eliminated and replaced with a cyclone outlet vacuum interface 314. In one embodiment, the interface 314 is realized in the form of a simple sump or transfer pan with a smooth rounded interior that helps prevent powder from accumulating therein. The pan 314 is provided with at least one vacuum inlet connection port 356. A second outlet port 354 (not shown in Fig. 22) may also be provided for connecting the interface to housekeeping vacuum and disposal.

An appropriate fitting is used at the outlet port 356 to connect thereto a vacuum line 318. The vacuum line 318 is connected at its opposite end 318a to a vacuum receiver system 320. The vacuum receiver 320 is a canister-like arrangement 322 that houses a removable filter 324. A vacuum source or pump 326 is used to produce a vacuum inside the receiver 320 and the vacuum line 318. This vacuum draws the powder that enters the cyclone transfer pan 314 out of the pan 314 and transfers it to the vacuum receiver 320. A portion of the powder collects on the filter 324 while most of it falls to the receiver lower cone 328.

A positive air pressure source 330 is used to pulse the filter 324 during a discharge cycle. A discharge cycle of the vacuum receiver 320 is that time during which the vacuum source is shut-off for a short period of time, with the filter being pulsed at that time also. At the bottom of the canister 322 is a discharge valve

arrangement 332 that opens under the force of gravity each time the vacuum pump 326 is turned off, allowing powder to fall into a sieve 334. In a typical system it is contemplated that the valve 332 will open about every 30 seconds or so during a spraying operation, but is only open for three to five seconds while the powder falls from the cone 328 into the optional sieve arrangement 334. The actual time periods and duty cycle may be varied as required for each system design. The sieve 334 may be a conventional vibrating sieve that filters the powder and discharges it back to the feed hopper 310. The short period of time, about thirty seconds, that powder accumulates in the vacuum receiver 320 is minimal compared to prior systems, and since it is at the end of the recovery process, has negligible impact on the efficiency of the recovery system 300. The short residence time of powder in the vacuum receiver 320 also prevents any significant accumulation of powder therein.

The vacuum receiver 320 is equipped with a releasable lid 336. The filter 324 is mounted on the top, so that during a color change operation the lid 336 is removed, what little powder is in the canister 322 is blown off, and the filer replaced with another filter for the next color. The use of color specific filters 324 speeds up the color change operation since such filters would be difficult to clean automatically. The filter in the sieve 334 is also typically a color specific filter that is replaced for a color change operation.

The powder recovery system 300 thus works as follows. The spray guns 20 receive powder from the pumps 308 and associated hoses 306. The powder overspray P laden air is extracted from the booth 10 and the powder is separated in the cyclones 42. As the powder descends to the cyclone vacuum interface pan 314 it is drawn out through the vacuum line 318 and conveyed to the vacuum receiver 320 where it is separated from the vacuum source and discharged to the sieve 334 and the back to the feed hopper 310. Thus, most of the powder overspray P is in near continual motion from the moment it leaves the gun 20 spray nozzle to the time it is returned to the feed hopper. The brief period of time that powder is accumulating in the vacuum receiver 320 permits the use of a powder conveyance arrangement having much less surface area, permitting much faster cleaning times than is realized by prior art systems that use surge hoppers, pinch valves and so forth that are connected to the cyclone. During a spraying operation, very little powder remains within the spray booth 10, the cyclones 42 or the receiver 320 subsystems.

It is noted that the various aspects of the vacuum recovery system and feed center in accordance with the invention may alternatively be used with other spray booth and powder extraction designs, and thus are not limited to use with the exemplary spray booth and extraction duct concepts. For example, various aspects of the recovery system and feed center may be used with a cartridge filter type extraction system.

CYCLONE VACUUM INTERFACE

With reference to Figs. 23, 24, 25 and 25A, the twin cyclone system 42 includes the side-by-side tangential inlets 54a,b and separate cyclone exhaust ports 42a,b. Each cyclone 42 also has a lower recovery cone 350a, b. The cyclone vacuum interface unit 314 in this embodiment is realized in the form of a sump or transfer pan 352 that is hinged onto the bottom of the twin cones 350a,b and secured by any suitable latch mechanism to allow easy opening of the pan 352 for cleaning. The directional arrows in Fig. 24 represent how the swirling powder generally moves within the interface 314 as the powder exits the cyclones. This swirling is a result of the air flow pattern in the cyclone and helps direct powder to the outlet ports 354, 356.

The vacuum interface 314 includes at least one outlet port 354, and preferably a second outlet port 356. Each port is a tubular structure that opens generally along or adjacent to the bottom surface 358 to form a smooth seamless outlet passageway 360 for the powder. As illustrated in Fig. 25A, each outlet port 354, 356 is generally circular in cross-section but at the opening to the pan 352 interior is formed into a wider rectangular cross-section 351. Other cross-sectional areas such as an ellipse could be used as required. The rectangular cross-sectional opening 351 has the same cross-sectional area as the round port 354, 356 but is more efficient in collecting powder from the pan 352 due to the swirling pattern of the powder as it enters the pan 352 from the cyclone lower cones 350a and 350b. This is because, as illustrated by the directional arrows in Fig. 24, the powder tends to sweep laterally across the pan 352 interior rather than coming straight down into the outlet ports 354, 356. Thus, a wider opening 351 with no less cross-sectional area of the opening as compared to the tubular port 354, 356 allows more time for the powder to be swept up by the same energy of the vacuum in the outlet port.

The lower cones 350a and 350b of the twin cyclones are provided with access doors 351a and 351b that facilitate cleaning of the cyclones during a color change operation.

One of the outlet ports 356 is connected to the vacuum line 318 by an appropriate compression fitting (not shown) or other suitable connection. Powder is thereby conveyed from the pan 352 to the feed center 46 by being drawn into the vacuum receiver 320. When used, the second port 354 may be connected to another suction line that sends the powder to a waste collection area.

<u>VACUUM RECEIVER UNIT</u>

With reference to Figs. 26-28, the vacuum receiver 320 includes the main canister body 322 having an integral lower conical collection portion 328. The vacuum receiver 320 is, in accordance with one aspect of the invention, installed in the feed center 46 (Fig. 22). In this embodiment, the canister 322 includes opposed trunnion-style transverse mountings 362. The trunnions 362 are pivotally mounted in the feed center 46 to allow the vacuum receiver to be rotated about an axis VR at least 90 degrees such that the top end of the receiver 320 is about at shoulder facing height with the canister oriented in a generally horizontal position. This allows an operator, after removing the canister lid 336, to blow off powder through the inside of the canister 322 towards a powder collection diffuser wall (382a) in the feed center 46 structure.

The canister 322 includes a series of latches 364 that secure the canister lid 336 to the canister body 322. The lid 336 also supports a powder filter 324 so that the filter can easily be changed by simply lifting off the lid 336 from the canister 322. The lid 336 further includes a connection 366 for the vacuum line 327 (Fig. 22). An air line connection 368 is also provided. The lid 336 further retains a pulse valve 370 that is used to apply high pressure air from the positive pressure source 330 to the filter 324 during a powder discharge period to dislodge powder from the filter 324.

At the lower end of the canister 322 is a valve actuator assembly 372. Fig. 27 shows the valve plate 332 open and Fig. 28 shows the valve plate 332 closed. The valve plate 332 is held closed when the plate 332 is in its raised or closed position whenever there is a vacuum within the receiver 320. When the vacuum is periodically interrupted, the valve plate 332 drops down by gravity into the open

position illustrated in Fig. 27 and powder inside the receiver 320 is discharged to the sieve 334.

An air actuated cam wheel 374 engages the underside of the valve plate 332. This wheel 374 is moved into engagement with the valve 332 by an air actuator 376. The air actuator 376 has an appropriate fitting 378 connected to a positive pressure air line (not shown). When pressurized air is supplied, the wheel 374 is rotated up into engagement with the valve 332 and closes the valve 332 against the bottom of the canister 322. When the vacuum is present in the receiver 320, the air pressure at the actuator 376 may be released as the vacuum alone will maintain the valve 332 shut and tightly sealed. An appropriate seal may be used around the bottom of the receiver 320 or other sealing mechanisms may be used as required. Periodically the vacuum is interrupted and the valve 322 falls open under the force of gravity, discharging any powder in the canister 322 into the sieve assembly 334. The control system 48 may be used to automatically time the vacuum interruption cycle and the actuator 376.

The canister 322 also includes a tangential opening 380. The outlet end 318a of the vacuum line 318 (Fig. 22) is connected to this opening 380 by any suitable device such as a re-usable compression fitting (not shown). With the rather rigid vacuum line 318 connected to the receiver 320, the receiver 320 will remain in its vertical orientation without a separate latching device, although a separate latching device may be used if required.

FEED CENTER

With reference to Fig. 29, the feed center 46 includes a wall structure 382 that partially encloses the feed hopper 310. The back wall 382a is preferably a diffuser wall that has a series of through holes (not shown). The wall forms part of a suction plenum behind the feed center 46, and a blower 340 draws powder from the interior of the feed center 46 through the back wall 382a and into a collection device or a powder waste disposal. In this manner, various components within the feed center 46, such as, for example, the suction tubes 312, the receiver 320 interior, the receiver lid 336, the pumps 308 and so forth, may be cleaned with air wands to remove excess powder during a color change operation, usually after the hopper 310 has been withdrawn from the feed center 46.

In Fig. 29 the pump suction tube array 312 (in the embodiment described herein there are a plurality of pumps and guns, however, any number of pumps and guns may be used as required) is illustrated in a raised position such as would be the

case initially during a powder changeover. The pumps 308 and suction tubes 312 are supported on a pump frame 384 (Fig. 30) that is raised and lowered by operation of a pneumatic cylinder 386 or other suitable linear translator. The frame 384 slides along a set of rails 392. A feed hose manifold 385 is used to connect all the feed hoses to their respective pumps 308 by installing the hose manifold on top of the pump frame 384.

The vacuum receiver 320 is mounted on the trunnions 362 which are pivotally supported on two legs 388 which are mounted on and extend downward from the ceiling or top 382b of the feed center wall structure 382. The sieve assembly 334 includes a powder filter 335 typically in the form of a screen mesh. The sieve 334 is mounted just below the vacuum receiver 320 and includes a discharge chute 390 that discharges filtered powder from the sieve to the feed hopper 310. The screen filter 335 is typically color specific and changed for each color changeover operation, as is the vacuum receiver 320 filter.

Fig. 30 illustrates additional features of the powder feed center 46 arrangement. The pump frame 384 is supported on a pair of rails or carriage 392 under the control of the actuator 386. An air tube diffuser 394 is supported below the bottom ends of the suction tubes 312 and supplies fluidizing air into the feed hopper 310 during a spraying operation. It should be noted that the term "feed hopper" should be broadly construed as including any suitable container for the powder, including but not limited to the powder bag. By providing a fluidizing air mechanism with the suction tubes, there is no need for a fluidizing hopper, and powder may be pumped directly from the original powder container. The vacuum connection 327 between the vacuum receiver 320 and the vacuum pump 326 is also illustrated in Fig. 30. A vacuum inlet 327a (see Fig. 29) is provided in the receiver top cover 336.

Figs. 30 and 32 also schematically show a pump and gun purge manifold system 396. The purge manifold system 396 is an array of air nozzles or valves "PA" that are installed in the lower portion of the feed center 46 and may, for example, fit under the hopper 310 even when the hopper 310 is positioned in the feed center 46. These nozzles correspondingly engage the lower end of the suction tubes 312 when the tubes 312 are lowered into purge position by the operation of the pneumatic cylinder 386. This is done as part of the color change operation and/or a gun and pump purge operation. In either case, the pumps 308 and suction tubes 312 are lowered into engagement with the purge system 396. Fig. 30 shows an intermediate

lowered position G of lower portion of the tube array 312 as it is lowered into engagement with the purge system 396. Fig. 32 illustrates the suction tubes 312 lower ends engaged with the purge manifold 396. Once the suction tubes 312 are connected to the purge system 396, pressurized air through an air line 395 is forced through the pumps 308, and the guns 20 to purge them of powder. Although the purge operation may also purge the feed hoses 306, it is also a common practice to change the feed hoses for a light to dark or dark to light color changeover as the hoses can be difficult to completely purge.

In accordance with another aspect of the invention, a powder pump 308 provides a powder flow path therethrough that is straight and "in-line", thereby eliminating any ninety degree or other turns within the pump 308. By "in-line" is meant that powder flows straight through the pump 308 from inlet to outlet on a single axis. Fig. 31 illustrates a preferred embodiment of the powder pump 308 in accordance with this aspect of the invention. In this embodiment, each pump 308 has an in-line pump. Each pump 308 includes a suction tube end 400 that slides into the top end of its respective suction tube 312. Each pump 308 also includes appropriate fittings 402 for atomizing and flow air. When pressurized air enters the pump 308, a suction is created in the suction tube 312 that draws powder from the hopper 310 into the pump 308. The pump 308 discharges the powder through an outlet 404 which may be, for example, a nipple that receives one end of a powder feed hose 306. The other end of the feed hose is connected to the corresponding spray gun 20 in the spray booth 10. The preferred design of the pump is optimal for color change operations. Because of the "in-line" structure, the powder flow does not have to make a ninety degree turn within the pump as would occur in a conventional powder pump. This permits the pump to be purge cleaned by compressed air of any residual powder much more quickly and easily than in prior pump designs. Although this preferred embodiment of the in-line pump is highly advantageous, the present invention is not limited to the use of this in-line pump and any pump may be used as required.

With reference to Figs. 33 and 34, the in-line pump concept exemplified in Fig. 31 may be used in combination with a straight through in-line spray gun concept. By providing a powder pump that has a straight through powder flow path, especially without any ninety degree or other significant turns in the flow path, and a straight through spray gun, an application system in accordance with this aspect of the invention achieves a flow of powder from the feed hopper 310 to a spray gun (410)

spray nozzle (410a) without any sharp turns in the flow path. In prior systems, the powder pump and/or spray gun typically include one or more ninety degree turns.

In the embodiment of Fig. 33, an in-line pump 400 is submerged in the powder P within a feed hopper 310. The pump 400 is, for example, positioned within a tube 401 that extends down into the hopper 310. The tube 401 includes appropriate fittings connected to an atomizing air supply 406 and a flow air supply 408. Powder is drawn up into the tube 401 from the bottom thereof. Fluidizing air may be supplied as required, or supplied via the tube 401 as described hereinbefore.

A powder feed hose 306 is connected at one end to the outlet of the pump 400 and at an opposite end to a powder inlet such as a feed tube of a spray gun 410. In one embodiment of the straight through spray gun 410, a gun such as described in co-pending United States Patent Application Nos. 09/667,663 filed on September 22, 2000 for POWDER SPRAY GUN and 09/490,099 filed on January 31, 2000 for POWDER SPRAY GUN, may be used, the entire disclosures of which are both fully incorporated herein by reference. Such a gun design is characterized in part by a single axis in-line powder flow path 412 from the gun inlet end through the nozzle 410a.

Fig. 34 illustrates an alternative embodiment of this aspect of the invention. In this embodiment, the pump 400 may be mounted on top of the feed hopper 310, rather than within the feed hopper. A suction tube 414 extends from the pump 400 down into the powder P. All other aspects of the embodiment of Fig 34 may be the same as in Fig. 33.

Fig. 36 illustrates another alternative embodiment of the in-line pump 400. In this example, the atomizing section 450 is axially separated from the flow air section 452 by a tubular extension 454. This permits the atomizing air function to be performed outside of the powder supply or at the spray gun.

Note in Fig. 31 that powder may be drawn axially up into the pump 400 as illustrated by the arrows 460 (Fig. 33). Alternatively, or in addition to the axially in flow of powder, the tube 401 may be provided with lateral openings 462 that allow the powder to enter the tube 401 from the side. This alternative arrangement may in some applications allow the submerged pump to be installed closer to the bottom of the feed hopper 310 or bag to pump out most of the powder therein.

The pump design 400 of Fig. 31 is one example of an in-line pump design that is suitable for the embodiments of Figs. 33 and/or 34. The pump 400 includes a

housing 420 within which are slip-fit inserts 422 and 424. These inserts 422, 424 define an axially tapered powder flow path 426. The inserts 422, 424 also define an air annulus 428 that is in flow communication with the flow air inlet 408. The flow air passes into an angled and constricted air jet 430 that is angled forwardly toward the pump outlet 404. The air jet 430 opens to the powder flow path 426 at an opening 432.

When pressured air is supplied to the flow air inlet 408, the resultant high velocity air flow into the flow path 426 creates a substantial negative pressure relative to the fluidized powder in the feed hopper 310. Powder is therefore drawn up into the pump 400 and transferred out to the feed hose 306 and spray gun 410,20.

The forward insert 424 defines an atomizing air passageway 434 that is in flow communication with the atomizing air inlet 406. The atomizing air passes into an angled and constricted air jet 436. The atomizing air jet 436 opens to the powder flow path 426 at an opening 438 that is downstream of the flow air opening 432. The atomizing air assists in further breaking up of the powder into smaller particles. Atomizing air is not always required, however. Still further, atomizing air may be provided at the spray gun rather than at the pump.

We have discovered that the use of an in-line pump, such as a pump illustrated in Fig. 31 for example, produces a more consistent film thickness across a wider area of the object being sprayed, as contrasted with a conventional powder pump that forces the powder to turn ninety degrees or so within a pump. This effect is illustrated in a representative manner in the graph of Fig. 35. This graph illustrates the relationship between film thickness across a width of the sprayed object for a conventional right angle pump (Graph A) and an in-line pump (Graph B) in accordance with the invention. Note that the thickness is more uniform over a wider area "C" for the in-line pump application system. This effect is further pronounced when the application system uses an in-line pump and a straight through gun as described hereinbefore.

The exemplary system 1 (Fig. 22) thus provides an arrangement by which powder overspray is scavenged on a real-time continuous basis from the spray booth 14 to a first collection device in the form of a cyclone system 42, and conveyed back to the feed center/application system 46 on a real-time near continuous basis. The powder is continually scavenged from a cyclone transfer pan so that the powder does not dwell within the recovery system until it reaches a vacuum receiver near

application system feed hopper. The powder has a minimal dwell time within the vacuum receiver 320, and the vacuum receiver 320 presents a minimal surface area and volume to clean compared to prior art systems that use positive air pressure to reclaim powder through a cyclone surge hopper and pinch valve arrangement.

COLOR CHANGEOVER PROCEDURE

A description of an exemplary color change procedure will now be provided. The specific order of the steps and the number and procedure of the steps are not necessarily required in all cases depending on the overall spraying system 1 design. For the exemplary spraying system 1 embodiment described herein, it is contemplated that a complete color changeover can be effected with only two operators, one primarily cleaning the booth 10 and cyclone 42, while the other primarily cleans the feed center 46. A single operator could alternatively be used or more operators if so required. In a prototype system, two operators are able to do a complete color change procedure in only about five minutes. Typical known systems are on the order of 15 minutes or more, with some as long as 45 minutes, and these other systems require much more cumbersome and less reliable clean out procedures.

When a color change procedure is to be performed, the oscillators 26 are stopped and the gun movers 24 move the guns 20 to the home position. The feed center sieve 334 stops vibrating and the fluidizing air to the hopper 310 is also stopped. The suction tubes 312 are raised out of the hopper 310 and the gun movers 24 retract the guns to a position outside the booth 10. The gun bodies are blown off as they are retracted. Positive air pressure directs the powder into the booth 10 where it passes into the extraction duct 40. All of these steps may be performed automatically under control of the main control system 48. One of the operators removes the feed hopper 310 from the feed center 46.

The feed center operator disconnects the vacuum line 318 from the cyclone collection pan 314, and blows off what little powder remains in the pan 314. Note that at all times the after-filter 304 system is operational so that any powder blown off the pan 314 is drawn up into the cyclone and exhausted to the after-filter 304. When the pan 314 is open, any powder from the extraction duct 40 also passes straight into the cyclone exhaust to the after-filter 60, because with the pan open the cyclones 42 are non-operational as separators.

With the vacuum pump 326 still on, the operator inserts one or more cleaning devices into the cyclone end of the vacuum line 318. For example, a foam cylinder or other spongy or soft body may be used. The cleaning device is pulled through the vacuum line 318 by the vacuum suction and exits inside the vacuum receiver 320. Several cleaning devices can be sent through the line 318 to assure thorough cleaning. Preferably the line 318 is a smooth walled seamless structure such as stainless steel or aluminum tubing.

Next the guns 20 and pumps 308 are purged. The control system 48 lowers the suction tube array 312 via the pump support frame 384 onto the purge manifold 396, sends purge air pulses through the suction tubes 312, the pumps 308, the hoses 306 and the guns 20. This powder from the purging is swept up into the extraction duct 40. After purging the suction tubes 312 and pump support frame 384 are raised. The outsides of the suction tubes 312 are blown off and the booth operator blows off the door 150 seams from outside the booth 10. The control system 48 is then instructed to stop the floor 16 rotation and raise the floor 16 to its sealed position against the bottom of the canopy 12. The booth operator can enter the booth 10 and walk on the floor. Using a pressurized air wand, the operator blows what little powder is on the booth walls and ceiling down onto the floor 16. The operator also blows powder off the extraction duct 40. After complete blow-off, the operator exits the booth 10, and the control system 48 is instructed to lower the floor 16 to its rotation position, and the blown-off powder is extracted to the cyclone system 42. At this time the seal blow-off valve 80 is also activated to completely blow powder off the seal 104 and draw powder off the floor 16 portion that extends outside the perimeter of the canopy 12 walls. The booth is thus completely purged of powder.

The vacuum receiver 320 is designed so as to rotate about the axis VR whereby the top of the canister 322 is about shoulder height and facing the feed center operator. The vacuum pump line 327 is disconnected from the canister top 336, as is the pulse air line from the positive pressure source 330. In this position, the operator can easily rotate the receiver 320 so that the lid 336 is facing the operator (i.e. facing the front of the feed center 46). The operator unlatches and removes the lid 336 and removes the color specific filter 324. The cleaning sponges are also removed. The operator then blows off the canister 322 interior, the lid 336 and related parts.

The sieve 334 top section is removed and the color specific filter screen 335 is removed. If a similar shade (light to light or dark to dark) color will be next used, the

sieve screen 335 is blown off. If a different shade will be used next, the screen is set aside for later cleaning. The sieve 334 is then cleaned and the proper screen 335 installed. Another color-specific filter 324 specific to the next color being sprayed is then mounted on the lid 336 and inserted into the canister 322. The lid 336 is re-latched and the canister 322 swung back to its vertical position (as shown in Fig. 22). The vacuum lines 318 and 327 are then reconnected to the receiver 320 and the pulse air line is also reconnected. While the feed center sieve and vacuum receiver are being cleaned, the other operator has opened access doors in the cyclone lower cones 350a and 350b and blows off all interior surfaces of the cyclones and any powder remaining in the pan 314.

Next the feed hose manifold 385 is removed and another manifold installed for the next color. The other ends of the new feed hoses are connected to the spray guns 20.

Another feed hopper 310 that contains the next color powder coating to be sprayed is then installed into the feed center 46 and the suction tubes and pumps 308 lowered into operational position. Lastly, the cyclone doors are closed, the collection pan 314 closed and the vacuum line 318 reattached to the collection pan 314. This completes the exemplary color change operation.

It will be readily appreciated that the color change procedure is greatly facilitated by the efficiency and thoroughness by which powder overspray is removed in a real-time manner from the booth 10 during a spraying operation due to the interaction between the rotating floor 16 and the overlaying extraction duct 40. However, the vacuum conveyance feature of the present invention, which conveys powder from the cyclone system 42 to the feed center/application system, may be used with any powder extraction and spray booth arrangement, including a cartridge filter type collection system.

It is intended that invention not be limited to the particular embodiments and alternative embodiments disclosed as the best mode or preferred mode contemplated for carrying out the invention, but that the invention will include all embodiments falling within the scope of the appended claims.

CLAIMS

Having thus described the invention, we claim:

1. A powder coating spray system comprising:

a spray booth that at least partially encloses a spray area in which powder overspray is produced during a spraying operation;

a powder feed apparatus that supplies powder to spray guns in said booth;

a powder extraction apparatus that removes said powder overspray from said booth and transfers said powder overspray to a first collection device; and

a vacuum source connected to said first collection device to transfer powder overspray from said first collection device to a second powder collection device, wherein said first powder collection device comprises a cyclone separator.

2. The system of claim 1 wherein said first collection device comprises a dual cyclone separator.

3. The system of claim 1 wherein said second collection device comprises a powder feed hopper in a feed center.

4. The system of claim 3 wherein said vacuum source is connected to a vacuum receiver and filter assembly that receives powder from said cyclone and supplies said cyclone-received powder to said powder feed hopper.

5. The system of claim 4 wherein said vacuum receiver is connected to said cyclone by rigid tubing; and a cleaning device that is drawn through said tubing by said vacuum source to clean powder from said tubing.

6. The system of claim 5 wherein said cleaning device is a foam-like mass.

7. The system of claim 4 comprising a sieve and vibrator assembly disposed between said vacuum receiver and said powder feed hopper.

8. The system of claim 1 wherein said powder extraction apparatus comprises a vacuum duct disposed within said spray booth to remove powder overspray therefrom.

9. The system of claim 8 wherein said powder spray booth comprises a floor that rotates about an axis; said vacuum duct being suspended above said floor and stationary with respect thereto to remove powder overspray from said floor as said floor rotates during a spraying operation.

10. The system of claim 8 wherein said first collection device comprises a cyclone separator; and wherein said vacuum duct is connected to an inlet of said cyclone.

11. The system of claim 1 wherein said first collection device comprises a cyclone separator having a powder outlet opening; and a cyclone outlet interface that receives powder from said cyclone outlet; said interface having at least one port connected to said vacuum source to remove powder from said interface as said powder enters said interface from said cyclone.

12. The system of claim 11 wherein said vacuum source draws powder from said interface at a rate at least as fast as a rate at which powder enters said interface from said cyclone.

13. The system of claim 11 wherein said interface comprises a second port connected to a second vacuum source so that powder from said cyclone outlet bypasses said feed center.

14. The system of claim 1 wherein powder is supplied to spray guns in said booth from a hopper in said powder feed apparatus; at least a portion of said powder being powder overspray from a spraying operation; said powder overspray being extracted from said booth during a spraying operation, transferred to said first collection device and then back to said hopper, to produce a substantially continuous closed loop flow of powder during a spraying operation.

15. A powder recovery system for a powder coating system, comprising:

a cyclone separator having a powder outlet;

a vacuum source; and

a powder extraction interface between said cyclone outlet and said vacuum source; said interface receiving powder from said cyclone outlet; said vacuum source transferring powder in said interface to a collection device.

16. The system of claim 15 wherein said vacuum source draws powder from said interface at a rate that is at least as fast as powder enters said interface from said cyclone outlet.

17. The system of claim 15 wherein said interface is connected to outlets of two cyclones operating side by side.

18. The system of claim 15 wherein said vacuum source is connected to a vacuum receiver having an inlet, a filter and an outlet; said receiver inlet being connected to an outlet port of said interface; wherein powder from said interface is

separated in said receiver and transferred through said receiver outlet to said collection device.

19. The system of claim 18 wherein said collection device comprises a powder feed hopper.

20. The system of claim 15 wherein said interface comprises a transfer pan in which swirling powder is received from said cyclone outlet.

21. The system of claim 20 wherein said transfer pan comprises a tubular port for connection to a vacuum line, said tubular port opening to said pan interior with a lengthened opening to facilitate powder passing into said tubular port.

22. The system of claim 21 wherein said lengthened opening has a cross-sectional area that is about the same as the cross-sectional area of said tubular port.

23. The apparatus of claim 15 wherein said collection device comprises a vacuum receiver, said receiver being rotatable about an axis to facilitate cleaning operations.

24. The apparatus of claim 15 wherein said interface is connected to said vacuum receiver by a seamless rigid tube.

25. A vacuum receiver for a powder recovery system, comprising:

a receiver canister; and

a support frame for said canister; said canister being mounted for selected rotation about an axis to facilitate cleaning the canister.

26. The receiver of claim 25 wherein said canister comprises a removable cover that carries a color-specific filter thereon.

27. The receiver of claim 25 wherein said support frame comprises part of a powder feed center for a powder spraying apparatus.

28. A powder spraying system of the type having a spray booth and a powder feed hopper for supplying powder to a spray hopper, comprising:

a powder extraction device in said booth that conveys powder overspray from the booth to a collection device outside the booth; and

a vacuum device that conveys powder from said collection device to the feed hopper.

29. The system of claim 28 wherein said collection device comprises a cyclone separator.

30. The system of claim 29 wherein said cyclone separator comprises two cyclones.

31. The system of claim 28 wherein said powder extraction device comprises a duct that extends over a floor of the booth and draws powder off the floor during a spraying operation.

32. The system of claim 31 wherein said floor rotates about a longitudinal axis of the booth and relative to said duct.

33. The system of claim 32 wherein the booth is generally cylindrical and the booth floor is circular.

34. The system of claim 32 wherein the booth and floor comprises very low conductivity composite material.

35. The system of claim 34 wherein the booth is self-supporting and is suspended in a cantilever manner over said floor.

36. The system of claim 34 wherein said floor is supported in a cantilever manner on a central hub.

37. The system of claim 28 wherein said vacuum device conveys powder from said collection device to a feed hopper.

38. The system of claim 37 wherein said vacuum device conveys powder from said collection device to said feed hopper via a sieve.

39. The system of claim 28 wherein said vacuum device is connected to a vacuum source; the vacuum in said vacuum receiver being periodically interrupted to permit powder discharge from said vacuum device.

40. The system of claim 39 wherein said vacuum device comprises a discharge valve at the bottom of said vacuum device that opens under the force of gravity when said vacuum device is not under vacuum.

41. The system of claim 40 comprising an actuator that closes said discharge valve.

42. The system of claim 28 wherein said feed device comprises a powder feed hopper.

43. The system of claim 42 wherein said feed hopper is installed in a powder feed center as part of an application system.

44. A quick change powder coating spraying system comprising:

a generally cylindrical powder spray booth comprising a canopy;

a generally circular booth floor that rotates relative to said canopy; said canopy being suspended over said floor;

a powder overspray extraction duct disposed in said booth to draw powder from said rotating floor during a spraying operation;

a cyclone separator that receives powder from said extraction duct; and

a vacuum conveyance system for vacuum conveying powder from said cyclone separator to a powder feed hopper.

45. The system of claim 44 wherein said feed hopper is part of a powder application system for powder spraying objects inside said booth.

46. The system of claim 44 wherein powder overspray is continuously scavenged from said floor into said duct during a spraying operation.

47. The system of claim 44 wherein powder is continuously scavenged from said cyclone to a vacuum receiver during a spraying operation.

48. A method for quick color change in a powder spraying system of the type having a spray booth and a powder spray application system, comprising the steps of:

continuously drawing powder from said spray booth during a spraying operation;

transferring powder from said booth to a first collection device;

conveying powder from said first collection device to said application system under vacuum.

49. The method of claim 48 comprising the step of drawing powder from the booth floor into a duct using low pressure air flow into the duct.

50. The method of claim 48 comprising the step of continuously conveying powder from said collection device to a second collection device.

51. The method of claim 50 comprising the step of periodically discharging powder from said second collection device to said application system.

52. A powder coating application system, comprising:

a powder spray booth; said booth comprising a canopy wall structure and a floor that is rotatable relative to said canopy wall structure;

a powder overspray extraction device for extracting powder overspray from said floor to a first collection device ; and

a vacuum recovery system that conveys powder overspray from said first collection device to a powder supply.

53. The system of claim 52 wherein said first collection device comprises a cyclone separator.

54. The system of claim 52 wherein said extraction device produces a low pressure region near said floor to draw powder overspray from said floor and transfer said powder overspray outside said canopy wall structure.

55. A method for cleaning a vacuum line for a powder recovery system, comprising:

producing a vacuum in a vacuum line connected between a first powder collection device and a second powder collection device;

using said vacuum to convey powder from said first powder collection device to said second powder collection device; and

cleaning said vacuum line by passing at least one wiping element through said line under force of said vacuum.

56. A powder coating application system, comprising:

a powder pump having a powder inlet and a powder outlet;

a powder spray gun having a powder inlet and a nozzle; and

a powder feed hose that connects said pump powder outlet with said spray gun powder inlet;

said powder pump having a powder flow path that extends in a single direction from said powder inlet to said powder outlet.

57. The system of claim 56 wherein said spray gun comprises a powder flow path that extends in a single direction from said spray gun powder inlet to said nozzle.

58. The system of claim 57 comprising at least one pressurized air source positioned proximate said spray gun to remove powder from said spray gun housing.

59. The system of claim 56 comprising a spray booth, said spray gun being at least partly disposed in said booth during a spraying operation, and a powder overspray extraction system that extracts powder overspray from said spray booth during a spraying operation.

60. The system of claim 59 wherein said extraction system comprises a spray booth floor that rotates and an extraction device that removes powder overspray from said rotating floor.

61. The system of claim 60 wherein said extraction device produces a low pressure air flow that draws powder overspray from said floor.

62. In a powder coating application system, a powder overspray sieve comprising a screen for filtering powder therethrough; said screen being removeable for a color change operation and powder color specific.

63. A powder overspray collection system, comprising:

a powder spray booth;

at least one powder spray gun disposed in said booth for spraying an object;

a powder supply for supplying powder to said spray gun;

said spray booth comprising a canopy and a floor that rotates relative to said canopy; and

a powder overspray collection system that transfers powder overspray from said spray booth to said powder supply; said collection system comprising:

a powder overspray extraction duct that draws powder overspray from said rotating floor and transfers said powder overspray to a powder separation device; and

a vacuum source that conveys powder overspray from said separation device to said powder supply.

64. A powder coating spray system comprising:

a spray booth that at least partially encloses a spray area in which powder overspray is produced during a spraying operation;

a powder feed apparatus that supplies powder to spray guns in said booth;

a powder extraction apparatus that removes said powder overspray from said booth and transfers said powder overspray to a first collection device; and

a vacuum source connected to said first collection device to transfer continuously powder overspray from said first collection device to a second powder collection device.